

MINING WASTE UTILIZATION IN THE PRODUCTION OF BUILDING MATERIALS

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Abstract

Possibilities of utilization of Olenegorsk iron ore deposit and Khibiny apatite-nepheline ore deposit overburden rocks (Kola Peninsula, Russia) in the production of building materials have been considered. It has been shown that overburden rocks minerals, particularly nepheline, chemically react with cement phase thereby consolidating the contact zone. According to the obtained results the overburden rocks can be used in road building, civil and industrial engineering.

Introduction

The problem of overburden waste utilization is urgent for the Kola Peninsula. Presently, out of over 50 million m³ of overburden rock dumped, as small as 10% is recovered. At the same time, we are faced with inadequate coverage of the domestic demand in crushed stone, which can be satisfied through the processing of dumped mining wastes.

The overview given below presents the capabilities of involving in construction the two types of overburden rock: Olenegorsk iron ore deposit (JSC Olkon) and apatite-nepheline ore deposit in the Khibiny mountains (JSC Apatit).

Overburden Rock of the Olenegorsk iron Ore Deposit

The Olenegorsk ore mining and processing enterprise (JSC Olkon) is a major iron concentrate producer in Russia. Its ferruginous quartzite is mined at five deposits. In recent years, about 10 million tonne of iron ore have been extracted there per annum. The gangue volume is over 11 million m³ at the stripping coefficient of 1.1 m³/tonne ore. The rock debris is metamorphic (gneisses of various composition) and igneous (granites, diabase, gabbro and pegmatite). The overburden rock is processed for crushed stone at a crushing and screening plant producing, at best, 2 million m³ of marketable crushed stone, which is 17% of current overburden output.

Up to 1998, JSC Olkon had processed only the overburden rock by 80% consisting of metamorphized biotite and amphibolite gneiss. Being of average quality (crushability brand of 600-800), this crushed stone was mainly used for railroad bedding. With time, the quality of crushed stone from igneous overburden produced at JSC Olkon was improved.

The Kola Centre for testing of building materials and articles at the Institute of Chemistry KSC RAS has carried out certification tests for an averaged representative batch of crushed stone with the fractions 5-20 mm. In mineral composition, it is represented by igneous (mostly gabbro-diabase and diabase) and metamorphic (gneiss, quartzite, amphibolite and granite-gneiss) rocks.

The trials have revealed fairly high physical-chemical characteristics of the product, fitting the following brands: in crushability – 1200; in abrasability - A-I; in frost resistance – F150-F200.

The content of harmful impurities does not exceed the standard-regulated values; the structure is stable to all kinds of decomposition; there are no limitations in terms of the radiation factor. The product can be used as railway bed ballast (its specific electric conductivity is low – 0.015 S/m).

Overburden Rock of the Khibiny Apatite-nepheline Ore Deposits

The Khibiny represents the world-largest alkaline massif. Its apatite-nepheline ore deposits are unique both in size, range and concentration of valuable components. The main producer of apatite concentrate (80% of Russia's total) is JSC Apatit. While extracting 30 million tonne of apatite-nepheline ore annually, they dump over 20 million m³ of overburden in which the main rock-forming mineral is nepheline. Since the content of nepheline in rock exceeds the 10% regulated by the State Standard 8267-93, its possible uses in construction require special studies.

The overburden rock of the Vostochny and Centralny mines of JSC Apatit essentially consists of two varieties: urtite and rischorrite [1]. Both contain nepheline (KNa₃[AlSiO₄]₄), feldspar (K[AlSi₃O₈]), pyroxene (NaFe[Si₂O₆]), and sphene (CaTiSiO₅), and also small quantities of apatite, titanomagnetite and biotite. It was established that these rocks are dense (2.7-2.8 g/cm³), strong (160-280MPa), with low values of water absorption (less than 0.4%) and abrasability (not more than 0.15 g/cm²), and a frost-resistance brand of no less than F300. In terms of the radiation factor, the rocks can be used in construction. Crushed stone from urtite and rischorrite has fairly high physical and mechanical characteristics: crushability – not less than 1200; abrasability A-I–A-II, frost resistance F150 (Table 1).

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Table 1. Physical-mechanical properties of crushed stone from overburden rock

Index	Crushed stone from urtite			Crushed stone from rischorrite		
	fraction, mm			fraction, mm		
	5-10	10-20	20-40	5-10	10-20	20-40
Bulk density, kg/m ³	1480	1520	1550	1360	1420	1480
Hollowness, %	50.1	48.6	45.5	50.3	49.9	47.8
Water absorption, %	2.2	1.3	0.4	1.9	1.1	0.6
Content of weak rock grains, %	2.8	0.5	0.2	4.0	0.7	0.3
Content of lamellated and prickly grains, % prickly	12.2	10.3	4.6	13.0	7.5	2.8
Content of dust-like and clay particles, %	0.10	0.18	0.16	0.40	0.30	0.10
Mass loss after compression in cylinder, % (in the denominator – the crushability brand)	<u>15.5</u> 1200	<u>14.7</u> 1200	<u>15.9</u> 1200	<u>14.6</u> 1200	<u>11.6</u> 1400	<u>12.3</u> 1200
Mass loss after testing in rack drum, % (in the denominator – the abrasability brand)	<u>25.2</u> A-II	<u>24.1</u> A-I	<u>28.7</u> A-II	<u>19.8</u> A-I	<u>22.2</u> A-I	<u>18.3</u> A-I
Mass loss after 150 freezing-defreezing cycles, %	3.4	2.2	1.5	3.5	3.9	4.5

The interaction of the principal rock-forming minerals of the overburden rocks with cement has been found to be characterized by mechanical adhesion and chemical interaction (weak, medium or strong – depending on the degree of blurring of the mineral-binding material interface up to the formation of an adhesion edge). It is evident from Fig. 1 that in all the rock-forming minerals, nepheline in particular, the chemical interaction with cement enhances with increase in the time of normal hardening or employment of heat-and-wet treatment.

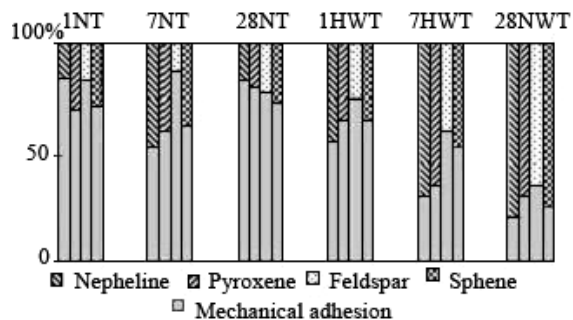
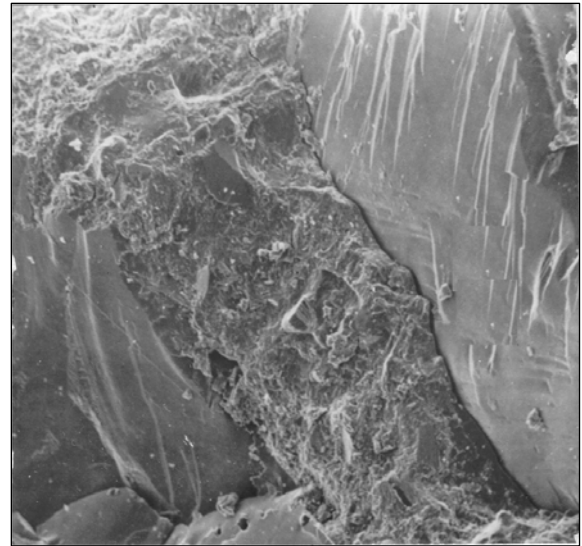


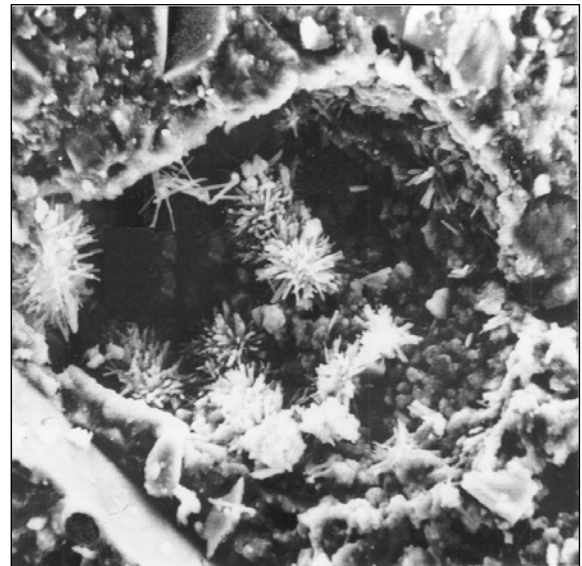
Figure 1. Interaction of urtite rock-forming minerals with cement: NH – normal hardening; HWT – heat-and-wet treatment; 1, 7, 28 – time of hardening in days

The minerals of the overburden rock (nepheline in particular) chemically interact with cement. In comparison with the latter, the microhardness in the nepheline-cement contact zone increases by 20-30%.

Scanning electron microscopy (SEM) of the nepheline and cement grain cleaved surfaces has revealed good contact of the minerals with hardened cement stone (Fig. 2(a)). As revealed by SEM, the contact zone (interface) of nepheline and hardened cement stone contains platelets of calcium hydroxide and new formations of hydrosilicates and hydroalumosilicates (Fig. 2(b)).



(a)



(b)

Figure 2. SEM images of a cement stone-nepheline grain spall (a) and the bottom of concrete pore (b). Mag..x450

X-ray diffraction also confirms the presence of these phases, as well as of sodium hydroalumosilicates: analcim ($\text{Na}[\text{AlSi}_2\text{O}_6]\cdot\text{H}_2\text{O}$) and natrolyte ($\text{Na}_2[\text{Al}_2\text{Si}_3\text{O}_{10}]\cdot 2\text{H}_2\text{O}$) which are minerals formed in the course of reaction of nepheline with cement (Fig. 3).

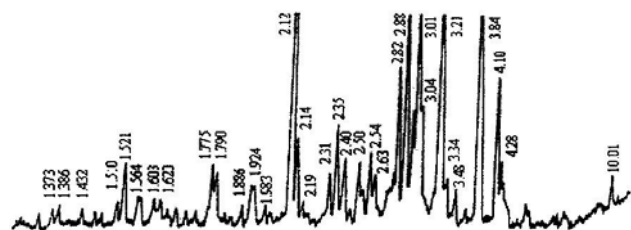
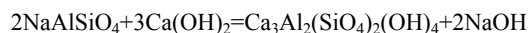


Figure 3. XRD pattern of the contact zone of concrete using urtite as a filling aggregate

As revealed by the microprobe analysis, changes in the principal chemical elements concentration, including K and Na, at the nepheline filler-cement stone interface occur very rapidly (Fig. 4). The scanning electron microscopy has shown that the interface region is consolidated (Fig. 5) which, together with increasing microhardness, is due to the formation of hydrogarnets (with a density of 3-3.5 g/cm³) as one of the phases of nepheline interaction with calcium hydroxide according to the following reaction:



One-year-long trials have confirmed the possibility of using nepheline-containing rocks as filling aggregates in concrete structures operated in underground mines of Apatit JSC. This is also confirmed by the satisfactory state of nepheline aggregate-based concrete structures produced from rock after 20 years of underground operation.

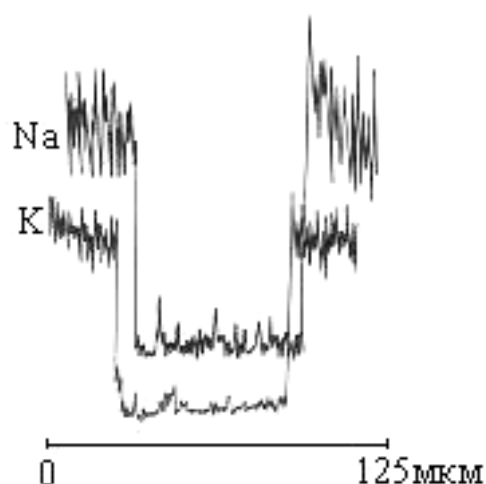


Figure 4. Concentration curves of alkali elements at the nepheline-cement stone-nepheline interface

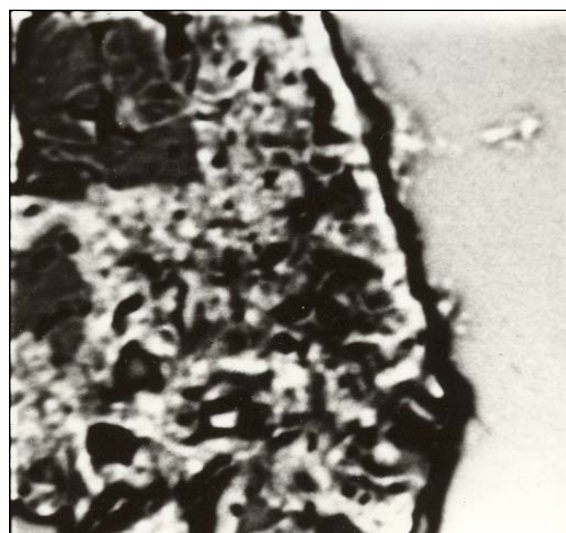


Figure 5. The nepheline-cement stone interface (in absorbed electrons e⁻).

It has been found that the crushed stone-sand mixtures, or graded crushed stone, from nepheline-containing overburden rock meet the requirements to road building materials. Crushed stone from urtite and rischorrite can be used as basic material for road bedding in all climatic zones [2]. The nepheline-containing rocks can also be used for making of road and airfield asphaltic-concrete surface. Both in plasticity and stiffness they compare favorably with hot bituminous concrete, have high abrasability and long service life.

Thus, the overburden rock of the Khibiny apatite-nepheline deposits can be effectively used in road, industrial and civil engineering.

References

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